Orbit Stability

I. DC Orbit Correction

A. System uses up to 360 broad-band (turn-by-turn) rf beam position monitors to compute corrections at 80 out of 317 steering corrector magnets in each plane.

B. Local steering corrections performed aperiodically at user request only.

C. Nonlinear “de-spiking” algorithm used to replace erroneous readbacks with average from neighboring units.

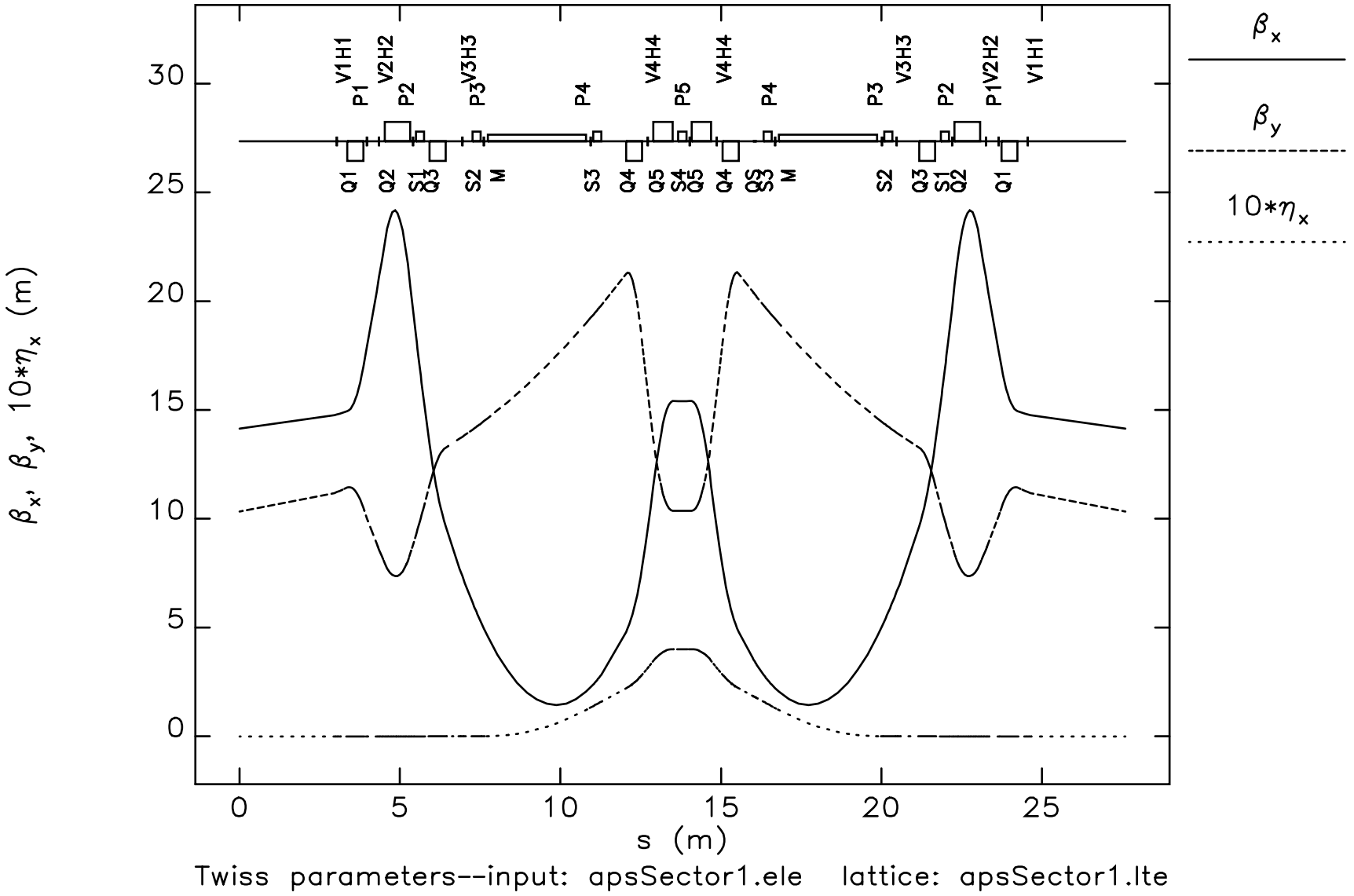
D. Open-loop intensity dependence compensation performed in parallel with global orbit correction.

E. Orbit length correction performed, which varies the rf frequency to hold beam centered in high-dispersion quadrupoles.

II. Present system generally meets beam stability specifications ($\pm$5 % of beam size)

A. Limitations on DC beam stability primarily deriving from long-term drift / intensity dependence, and fill-to-fill reproducibility deriving from bunch pattern sensitivity.

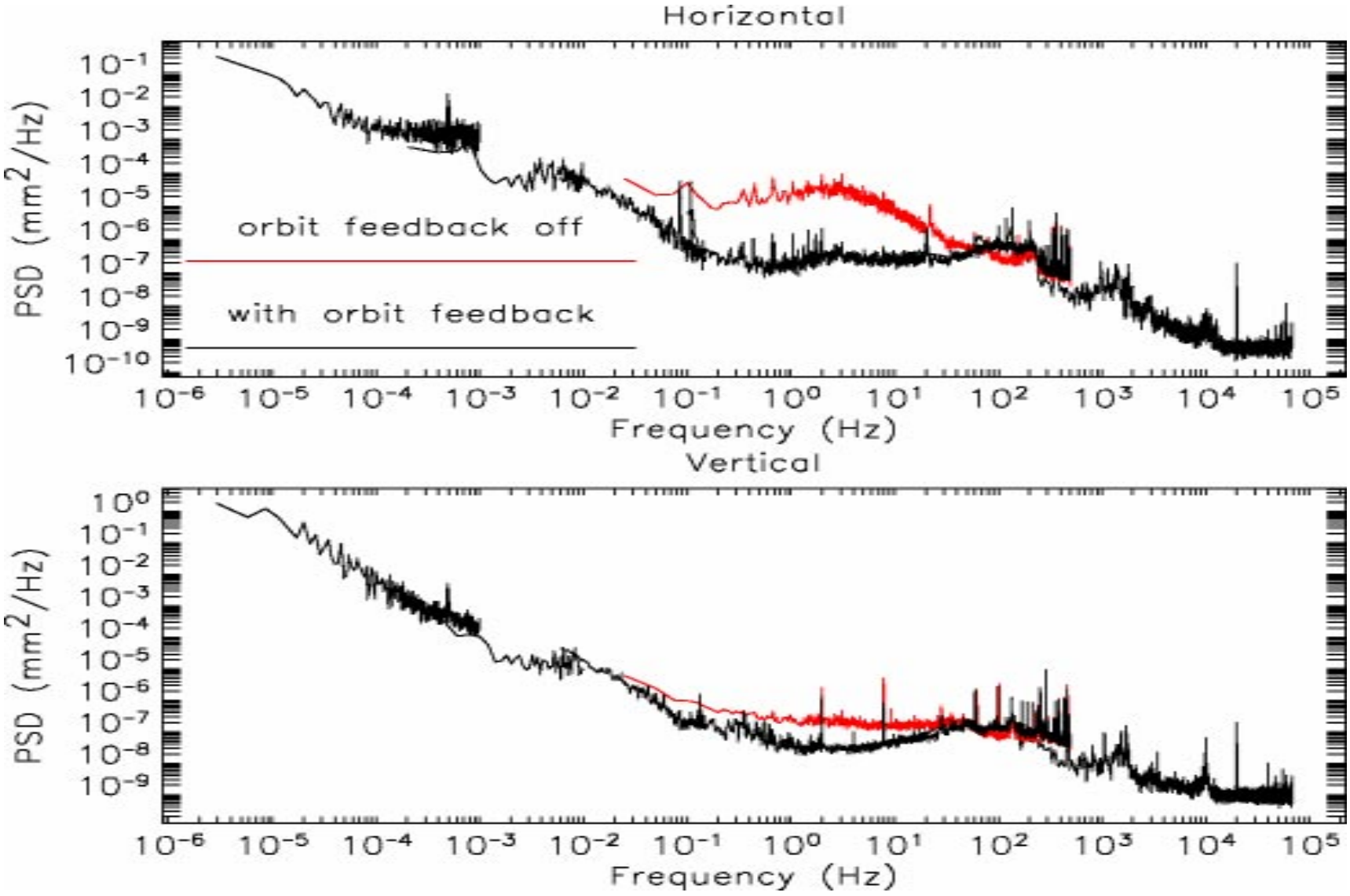
B. Addition of narrow-band electronics at 21 ID source points expected to improve fill-to-fill reproducibility and long-term drift performance.


V1H1
P1
V2H2
P2
P3V3H3
P4
V4H4
P5
V4H4
P4
P3
V3H3
P2
P1V2H2
V1H1
Q1
Q2
S1
Q3
S2
M
S3
Q4
Q5
S4
Q5
Q4
QS
S3
M
S2
Q3
S1
Q2
Q1
30
25
20
15
10
5
0
0
5
10
15
20
25
s (m)
β_x, β_y, $10*\eta_x$ (m)
β_x
β_y
$10*\eta_x$
Twiss parameters--input: apsSector1.ele lattice: apsSector1.lte

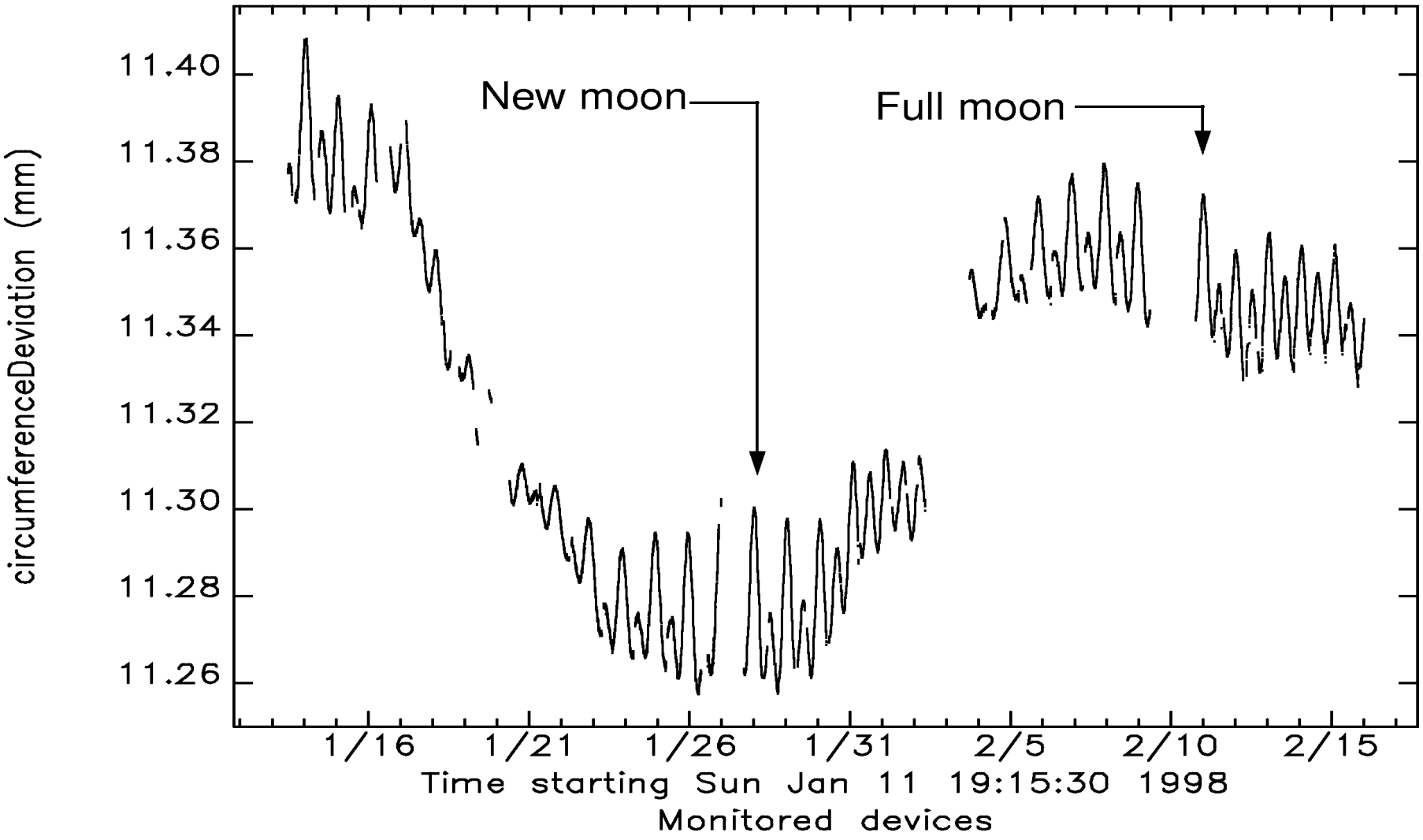
Beam Stability Performance to Date (5/98)

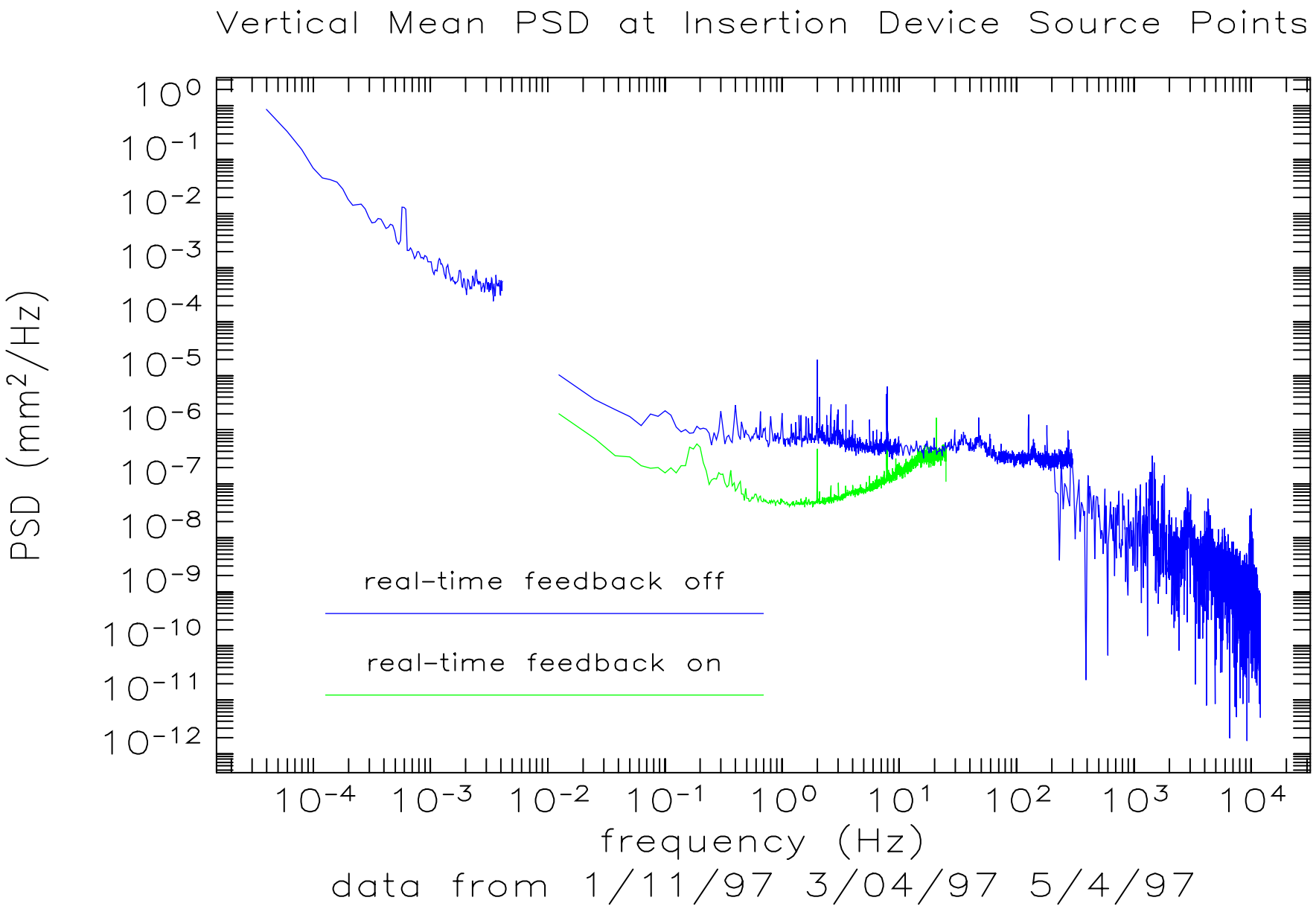
Frequency Band	**Horizontal Motion ΔX (microns rms)**	**Vertical Motion ΔY (microns rms)**	**Limitations**
Low Frequency Drift, (10^{-6} - .017 Hz)	$< \sigma_x$ *	**2.5 to 20**	Electronics Intensity Dependence, Mechanical and Electrical Thermal Effects, RFBPM Bunch Pattern Dependence, IDXBPM stray radiation.
Jitter (.017 - 30 Hz)	**< 4.5, or 1.3% σ_x** *	**< 1.8, or 10% σ_y** *	High Bandwidth Corrector Availability, IDXBPM stray radiation
High Frequency 30 - 500 Hz	**< 12.4**	**< 7.5**	Power Supply, RF Voltage Stability
Very High Frequency 0.5 - 135 kHz	**5**	**6**	RF Voltage Stability, Multibunch Instabilities
Broadband TOTAL	**14.1 + drift**	**10.1 to 22.3**	Long Term Drift

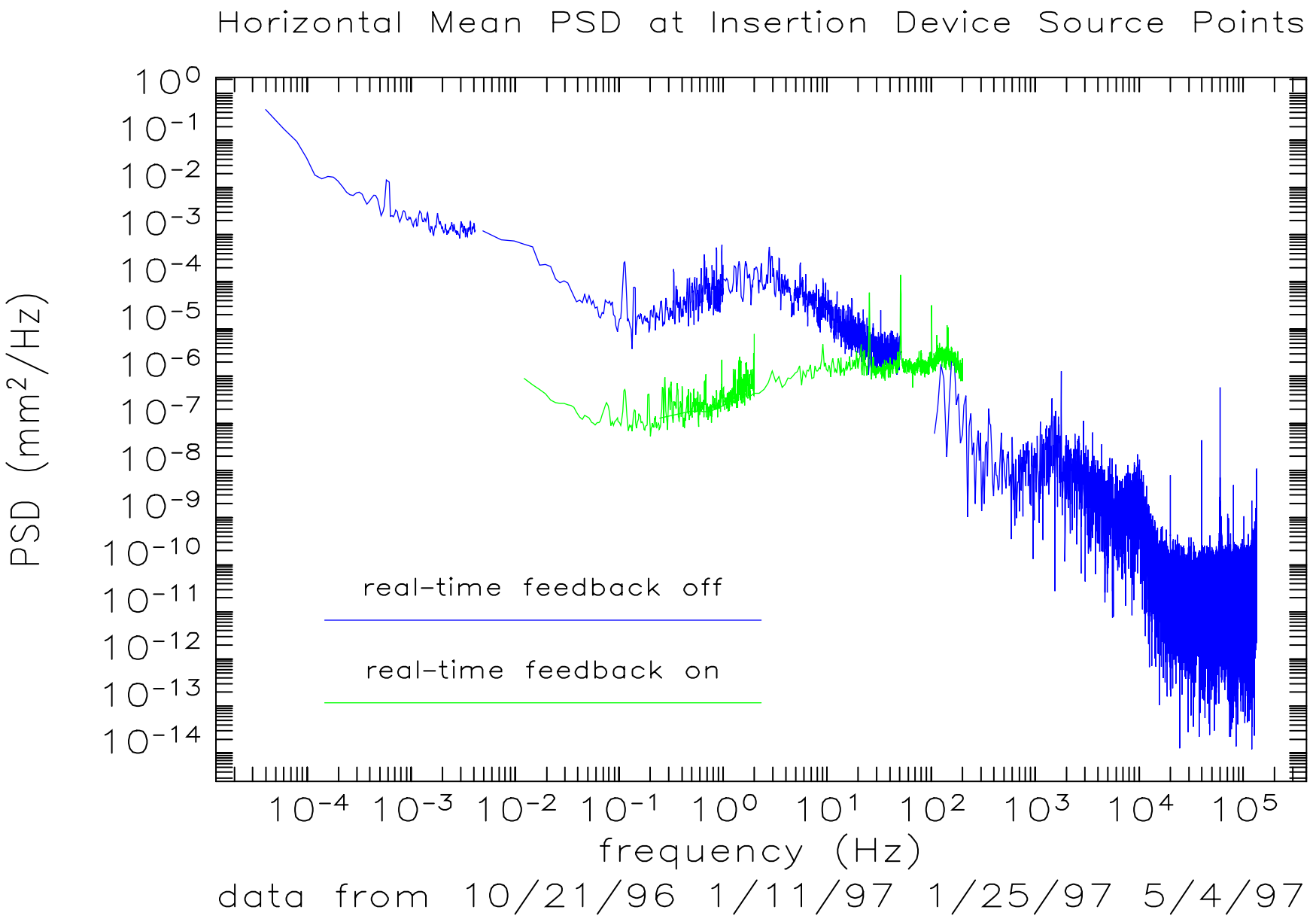
* : Beam sizes σ_x = 335 microns, σ_y = 18 microns @ 1% coupling


Horizontal
PSD (mm²/Hz)
orbit feedback off
with orbit feedback
Frequency (Hz)
Vertical
PSD (mm²/Hz)
Frequency (Hz)

Measured deviation of APS storage ring circumference
from 1104 meter design value for operational period 98-1




Vertical Mean PSD at Insertion Device Source Points
PSD (mm²/Hz)
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
real-time feedback off
real-time feedback on
10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 10⁰ 10¹ 10² 10³ 10⁴
frequency (Hz)
data from 1/11/97 3/04/97 5/4/97


Horizontal Mean PSD at Insertion Device Source Points
PSD (mm²/Hz)
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
real-time feedback off
real-time feedback on
10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 10⁰ 10¹ 10² 10³ 10⁴ 10⁵
frequency (Hz)
data from 10/21/96 1/11/97 1/25/97 5/4/97

Real-Time Closed Orbit Feedback

I. Commissioned 7/97 supporting user beam.

II. Beam stability better than 1.8 microns rms vertically and 5.0 microns horizontally in the band 0.01 to 30 Hz

III. Employs up to 160 broadband rf BPMs, and 38 correctors which are updated at a 1.6 kHz rate.

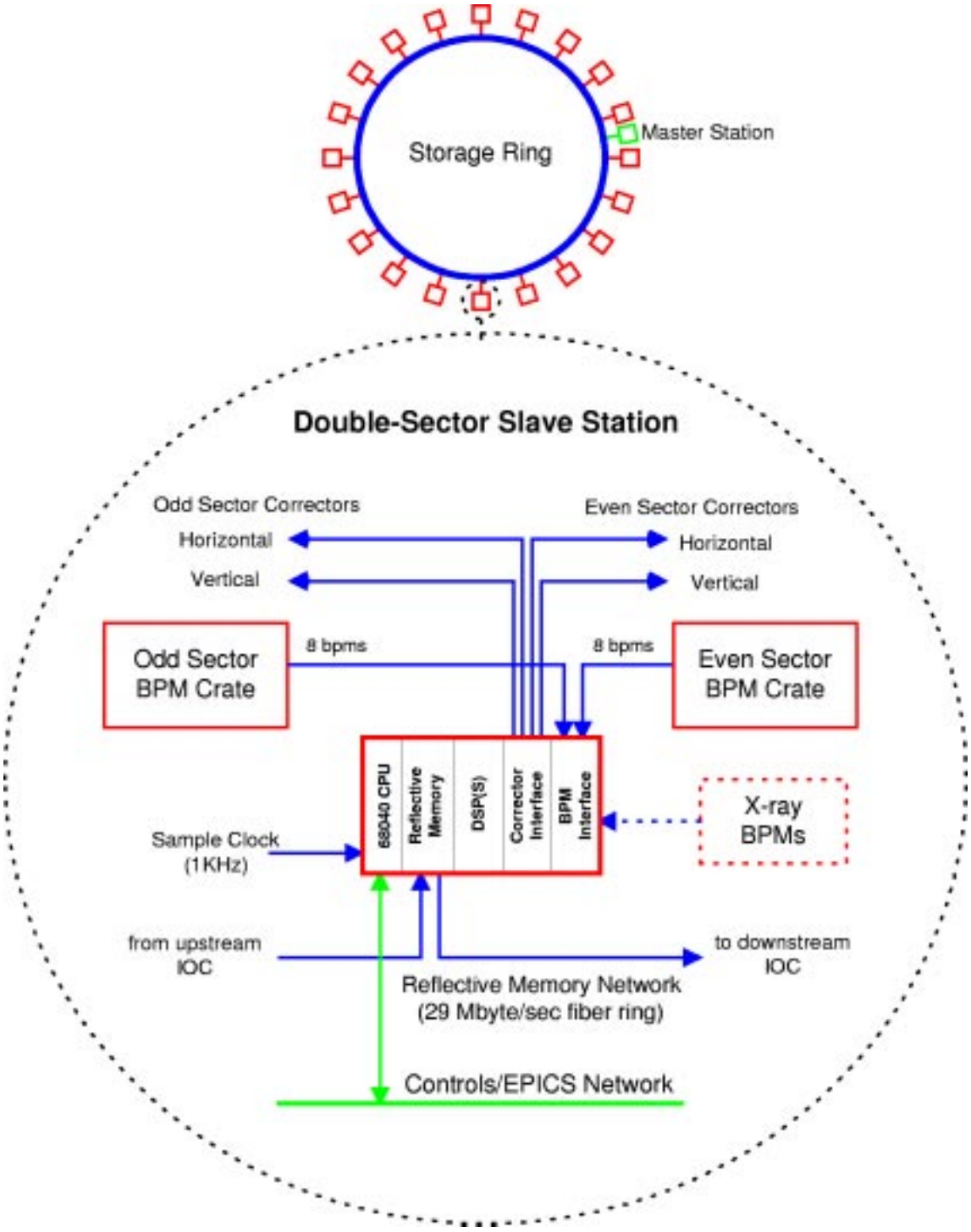
IV. Provides powerful diagnostic for identification of noise sources and malfunctioning BPMs.

V. Upgrade planned to incorporate up to 80 steering correctors for improved performance.

   A. AC behavior of additional correctors differs significantly from those presently in use as a result of eddy currents in thick-walled aluminum vacuum chamber. Present set of 38 correctors mounted at thin-walled Inconel spool pieces yielding broadband performance.

VI. Power supply controls upgrade in process to allow 18 bit set point resolution and additional diagnostics.

VII. Narrowband rf bpm and X-BPM data available to feedback system. Future algorithms will incorporate this data.

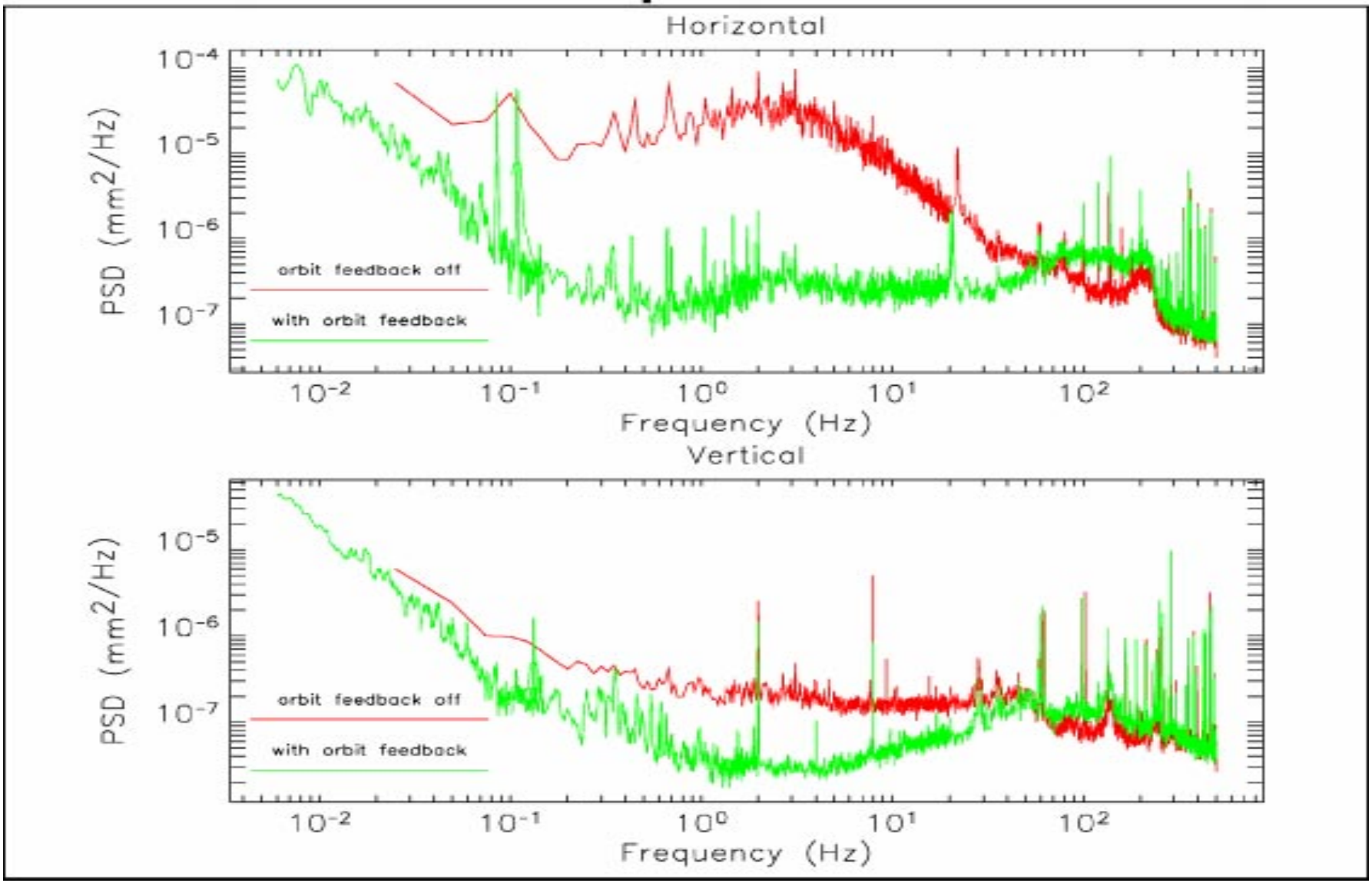

Storage Ring
Master Station
Double-Sector Slave Station
Odd Sector Correctors
Horizontal
Vertical
Even Sector Correctors
Horizontal
Vertical
Odd Sector BPM Crate
8 bpms
8 bpms
Even Sector BPM Crate
68040 CPU
Reflective Memory
DSP(S)
Corrector Interface
BPM Interface
X-ray BPMs
Sample Clock (1KHz)
from upstream IOC
to downstream IOC
Reflective Memory Network
(29 Mbyte/sec fiber ring)
Controls/EPICS Network

Orbit Stability at Insertion-Device Source Points

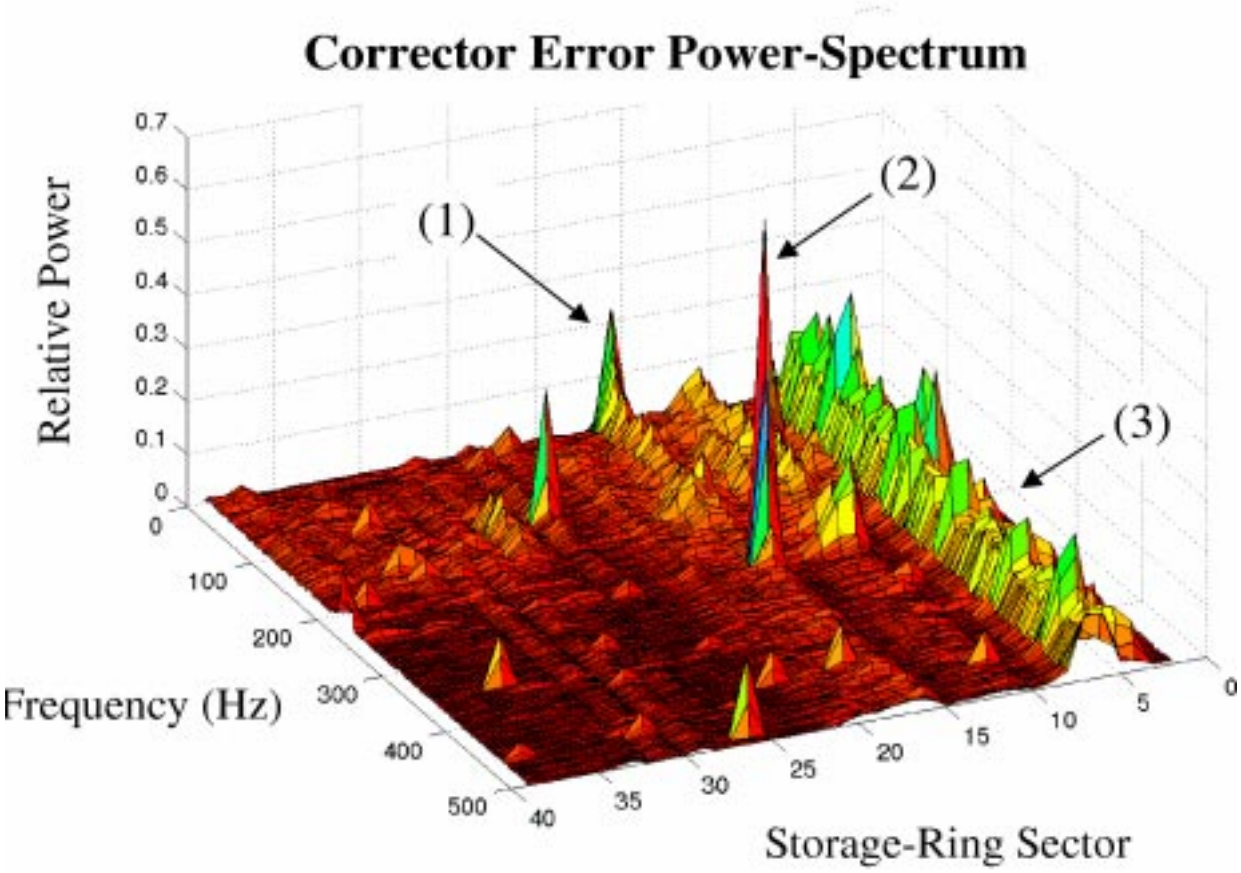
	Horizontal		Vertical	
	No F/B	F/B on	No F/B	F/B on
Required orbit stability (rms) (with 10% x-y coupling)	17.5μm		4.5μm	
Orbit motion 0.016Hz-30Hz (rms)	18.4μm	4.4μm	3.1μm	1.8μm
Orbit motion 0.25Hz-500Hz (rms)	20μm	13.2μm	7.4μm	7.5μm
Beam size at I.D. source points (rms) (inferred from S35BM @ 100mA)	335μm		18μm	
Beta at I.D. source points (design)	17m		3m	

Measurements were taken during the APS "98-2" user run with 1% x-y coupling

Orbit Motion Power Spectra at ID Source Points



Roadmap of Horizontal Sources (September 1997)



(1) Low-frequency random noise from sextupole power supply with poor regulation.
(2) Narrow-band source at 248Hz from oscillating corrector power supply.
(3) Broad-band noise caused by bad BPM in sector 6 (not real orbit motion).

Reduction of X-Ray Beam Position Monitor Systematic Errors by Modification of the Lattice

I. Insertion device X-BPMs are subject to the influence of variable stray radiation sources emanating from nearby bending magnets, quadrupoles, sextupoles, and steering correctors.

II. Introduction of a chicane into the lattice eliminates nearly all of the stray radiation from the X-BPM field of view.

III. Ray tracing studies show feasibility of concept.

IV. Sector 34 chosen for initial trial, December, 1998.

A. Direct comparison of broadband, narrowband and x-ray beam position monitors possible here.

B. Novel ideas such as the use of radiation from the correctors located immediately upstream and downstream of the insertion device as a diagnostic will be investigated.

C. A special-purpose X-BPM blade actuator (beam profiler) with a large scan range is being installed in the 34-ID beamline front end during the October shutdown to map out the radiation field patterns both before and after performing lattice change.

Concept for Elimination of X-BPM Background Signals